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HYPERVELOCITY IMPACT EFFECTS ON SOLAR CELLS

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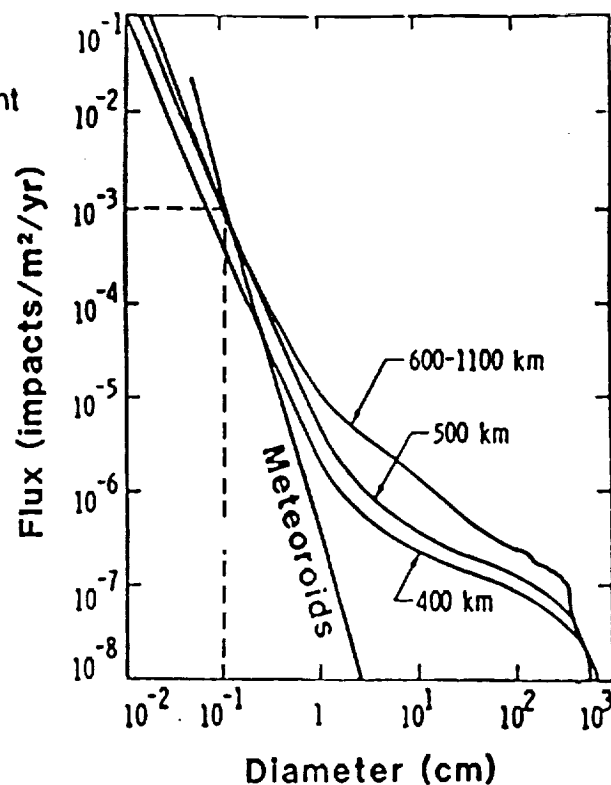
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Introduction

One of the space hazards of concern is the problem of natural matter and space debris impacting spacecraft. This phenomena has been studied since the early sixties and a methodology has been established to determine the relative abundance of meteoroids as a function of mass. As the mass decreases, the probability of suffering collisions increases, resulting in a constant bombardment from particles in the sub-micron range. The composition of this "cosmic dust" is primarily Fe, Ni, Al, Mg, Na, Ca, Cr, H, O, and Mn. In addition to mechanical damage, impact velocities greater than 5 k m/sec can produce shock induced ionization effects with resultant surface charging and complex chemical interactions. The upper limit of the velocity distribution for these particles is on the order of 70 km/sec.

The second source of particulate matter is due to the presence of man and the machinery needed to place satellites in orbit. This "man made" component of the space debris consists of waste, rocket exhaust, and debris caused by satellite break-up. Most of the particles are small. However as the size increases, debris purposefully thrown overboard such as garbage and human waste, combined with paint chips, plastic, wire fragments, bolts, etc., become formidable hazards which completely dominate the distribution function for some orbits. These larger fragments can produce penetration and spalling of the thick metallic structures associated with spacecraft. Of course, at the upper limit of the man made contribution is derelict satellites and spent boosters. While the probability of impact with these larger objects is small, it has been necessary to "move the Space Shuttle" to avoid possible impact. The calculated debris spectrum as a function of altitude is shown in figure 1.

Figure 1. Space Debris Environment



The "man-made" contribution to the space debris problem is increasing and dominates the distribution for some altitudes. The particles most often encountered is aluminum oxide, associated with fuel residue, and paint chips and can have a wide range of particle sizes. It has been stated that the design of spacecraft will have to take the debris evolution into account and provide additional suitable armor of key components in the near future.

The purpose of this work was to subject samples from solar power arrays, one of the key components of any spacecraft, to debris flux typical of what it might encounter in space, and measure the degradation of the power panels after impact.

Experimental

The facility used to conduct the impact tests is a "plasma drag" hypervelocity (HYPER) accelerator located in the Space Power Institute facility at the Auburn University. The facility is shown schematically in figure 2.

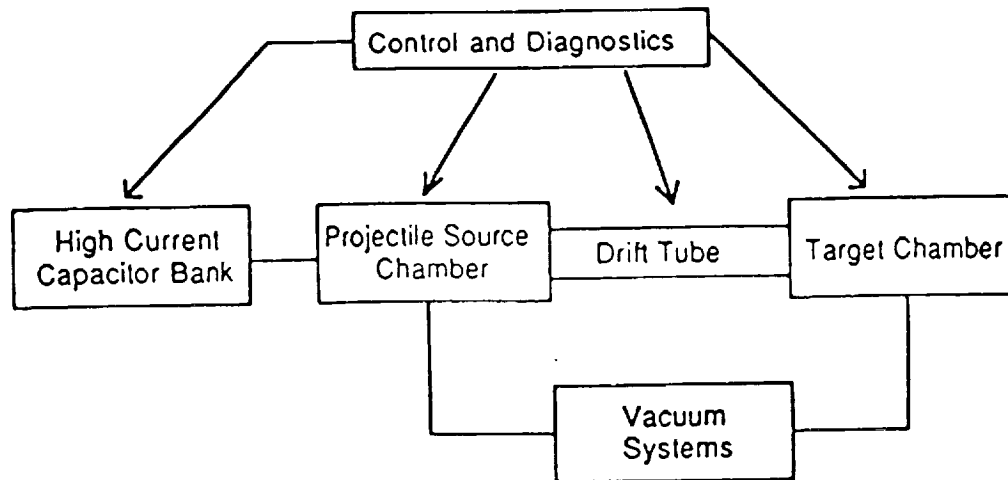


Figure 2(a). Facility Schematic

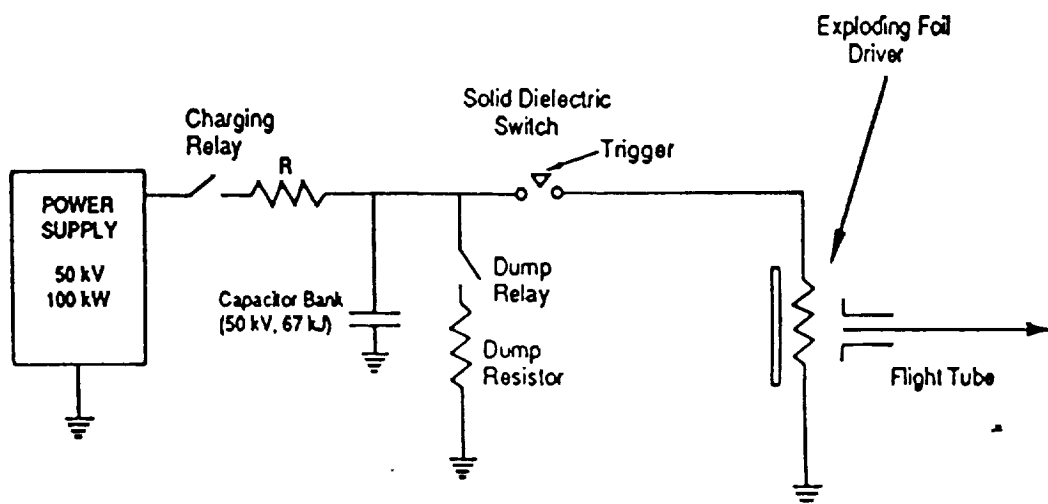


Figure 2(b). Current Source Circuit

With this device, particle velocities as high as 15 km/sec have been measured for particles on the order of 100 microns. For these experiments, particles as large as 400 microns in diameter were used. The diagnostics used to characterize the impacts were "streak camera" records, electrical diagnostics as required and a sub-micron ballistic membrane for measuring the approximate particle size. Each specimen was scanned for impact events and the scans recorded on VHS tape for analysis. The sizes of the craters and the depth of the damage zone was recorded for later analysis with the technical staff of the Rocketdyne Laboratories. The table below is a listing of the experiments conducted, the diagnostics used, the impacting material, and the analysis done for each experiment.

Table 1

SHOT #	DATE	TARGET	TEST TYPE	TEST DIAGNOSTIC	PARTICLE TYPE	PARTICLE SIZE	DATA PROVIDED
C 19	2-25-92	CELL 11-219	Passive	Streak Camera	Aluminum Oxide	100 micron nom.	Streak Photo
							Pre-Test Photo
C 20	2/25/92	CELL 11-221	Passive	Streak Camera	Aluminum Oxide	40 micron nom.	Post-Test Photo
							X-Y Streak Data
C 21	2/25/92	CELL 11-232	Passive	Streak Camera	Olivine	100 micron nom.	X-Y Site Log
							Site Physical Data
							Site Velocity
							Projectile Size
							Velocity Distrib.
							Site Video Log
							Videographs
							Spreadsheet
							Data Disk
C 22	2/26/92	FCC-Test 1	Passive	Streak Camera	Aluminum Oxide	100 micron nom.	Streak Photo
							Pre-Test Photo
							Post-Test Photo
							X-Y Site Log
							Site Physical Data
							Velocity Distrib.
							Site Video Log
							Spreadsheet
							Data Disk
C 65	11/6/92	FCC-Test 2	Active	Streak Camera	Aluminum Oxide	76 micron nom.	Streak Photo
				Plasma; Bias Volts			Pre-Test Photo
C 66	11/6/92						Velocity Distrib.
		FCC-Test 3	Active	Streak Camera	Aluminum Oxide	122 micron nom.	Spreadsheet
				Plasma; Bias Volts			Data Disk
C 67	11/6/92	CELL 11-376	Passive	Streak Camera	Aluminium Oxide	122 micron nom.	Streak Photo
							Pre-Test Photo
							Velocity Distrib.
							Spreadsheet
							Data Disk

Results

The analysis of the photocells under illumination was done by the Rocketdyne staff. In general, the results of this work can be summarized as follows:

- The velocity range up to 10 km/sec was covered in the impact events characterized in these experiments.
- The number of impacts on each specimen in this series of experiments represents several years of space exposure.
- Cover plate damage and some damage to the underlying cells does take place over the range of velocities investigated.
- On the cable bundles, no arcing to the simulated space plasma was observed for the potentials used in the experimental set-up.
- Extrapolated degradation of a solar power system such as that of the Space Station is minimal for the range of exposure covered in these experiments.